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ELECTRON MICROPROBE STUDY OF PLATINUM GROUP MINERALS FROM THE TULAMEEN COMPLEX, BRITISH COLUMBIA

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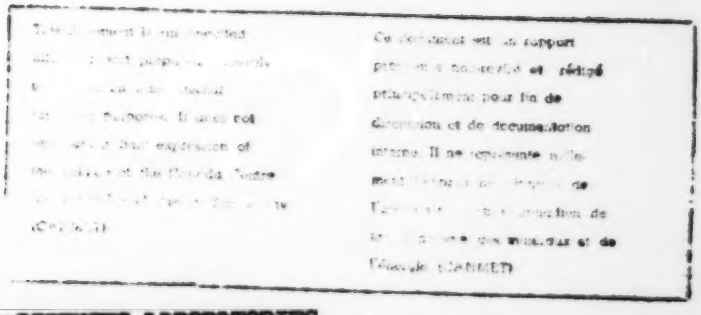

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INTRODUCTION

Five polished sections from 3 samples (GN87-146, GN87-147, GN87-148) were examined in detail at the request of Dr. G.T. Nixon because of CANMET's expertise in the analysis of these types of samples. Selected platinum-group minerals (PGM) were analysed in these polished sections and within polished thin sections. All samples were provided by Dr. G.T. Nixon on behalf of the Geological Survey Branch, Ministry of Energy, Mines and Petroleum Resources, Victoria, British Columbia under a 50:50 cost recovery agreement. The platinum-group elements (PGE) occur as PGM or as minor constituents of other minerals. A brief description of the polished sections follows.

RESULTS

Sample GN87-146

This sample consists primarily of serpentine with minor disseminated chromite. The chromite often exhibits Fe-rich rims (ferritchromite) and contains fractures filled by calcite/dolomite. Other minerals occurring in minor to trace amounts are magnetite, Ni sulphides (possibly millerite and heazlewoodite), Ni antimonides (breithauptite plus two others), Ni arsenides (maucherite plus another), a Ni-Co-Fe sulphide (typically exhibiting an eutectoid texture in the ferritchromite rims or in silicates), native copper and copper oxide grains.

Six to seven different PGM species were found but the most common are Pt alloys, themselves representing several species including tetraferroplatinum(?), isoferroplatinum(?) and tulameenite(?). A total of 25 Pt alloy grains were confirmed in the sections. They generally occur as euhedral inclusions in chromite ranging from <2 μm to 30 x 35 μm in size and are also frequently associated with other PGM. The other PGM, in decreasing order of frequency are: geversite ($PtSb_2$), Rh and Ir sulpharsenides (hollingworthite/irarsite series, i.e., RhAsS-IrAsS), sperrylite ($PtAs_2$) and single grains of erlichmanite (OsS_2) and laurite (RuS_2). Platinum also occurs as a solid solution in native copper (up to 32.4 wt %),

INTRODUCTION

Cinq sections polies de trois échantillons de minéraux (GN87-146, GN87-147, GN87-148) ont été étudiées de façon détaillée à la demande de G.T. Nixon, Ph.D. parce que CANMET possède les compétences dans l'analyse de ces types d'échantillons. Les minéraux sélectionnés du groupe platine (MGP) retrouvés à l'intérieur de ces sections et des plaques minces ont été analysés. Tous les échantillons ont été présentés par M. G.T. Nixon, pour le compte de la Direction de la Commission géologique, Ministry of Energy, Mines and Petroleum Ressources, Victoria, Colombie-Britannique, dans le cadre d'une entente à frais partagés. Les éléments du groupe platine (ÉGP) se retrouvent sous forme de EGP ou de constituants secondaires d'autres minéraux. Une brève description des sections polies est également présentée.

characteristically occurring as part of complex multimineralic grains together with Ni antimonides/arsenides and other PGM.

Sample GN87-147

Whereas silicates are the major constituents, this sample contains areas of massive chromite with typical calcite/dolomite fracture-filling. Trace quantities of Ni sulphides (millerite/heazlewoodite) and Ni arsenide (maucherite?), native Cu, native Ag and a Cu oxide occur. The only PGM found in this sample are Pt alloys, consisting of 4 grains (10 x 10 to 20 x 25 μm), all included in chromite.

Sample GN87-148

This sample consists principally of chromite (sometimes fairly massive) and silicates (mainly serpentine). Calcite/dolomite occur as fracture-fillings in chromite. Magnetite is a minor constituent, and, as in the other samples, minor to trace amounts of Ni sulphides, arsenides and antimonides and native copper also occur.

The PGE occur in the form of several PGM, including Pt alloys, geversite, an undefined Pt oxide and irarsite as well as solid solutions in native copper (up to 36.5 wt % Pt) and also possibly in Ni antimonides. Many grains are complexly intergrown and show evidence of alteration. The largest grain found in all three samples was a 50 x 120 μm grain of a Pt oxide intergrown with geversite, Pt-bearing native Cu, a Ni antimonide and a Ni oxide(?) enclosed in a vein of (Mg,Fe) silicate (serpentine?) within chromite.

Quantitative electron microprobe analyses are given in Table 1-6 and selected photomicrographs show the principal features of the PGM and the PGE-bearing minerals (Fig. 1-16).

DISCUSSION

Some of the PGM, especially the Pt alloys, are different to those previously found as placer nuggets and smaller grains from the Tulameen area. The principal Pt alloy, tentatively identified as tetraferroplatinum (ideally PtFe), has compositions lying near the centre of a triangle bounded by

tetraferroplatinum (Pt_2Fe_2) - tulameenite (Pt_2FeCu) - ferronickelplatinum (Pt_2FeNi). One tulameenite(?) grain lies on the Pt_2FeCu - Pt_2FeNi join and another on the Pt_2FeCu-Pt_2CuNi join. In addition, significant quantities of Pt occur in a variety of native copper and, possibly also in a nickel antimonide (together with Ir). One of the three samples also shows clear evidence of alteration under high fO_2 conditions with breakdown of geversite to form an, as yet, undefined Pt oxide mineral.

CONCLUSION

The unexpectedly complex PGE mineralogy requires considerably more study to fully understand the PGE distribution and, possibly, obtain a clearer understanding of the geochemistry and the paragenesis in order to provide better guides to exploration and mineral processing.

Table 1. Electron microprobe analyses of Pt-alloys from Tulameen

Anal. No.	Weight per cent*									
	Pt	Rh	Pd	Ir	Os	Fe	Cu	Ni	Sb	Totals
A. Tetraferroplatinum?										
1.	76.8	n.d.	n.d.	0.46	n.d.	13.4	4.7	4.1	0.23	99.69
2.	76.6	0.26	0.30	0.25	n.d.	13.7	3.2	4.6	n.d.	98.91
3.	77.2	0.34	0.30	0.38	n.d.	13.9	2.9	4.3	n.d.	99.32
4.	77.1	0.26	0.29	0.17	n.d.	13.0	3.2	4.7	n.d.	98.72
5.	72.6	0.43	0.50	3.5	n.d.	14.8	3.3	3.9	n.d.	99.03
6.	73.3	0.38	0.50	1.9	n.d.	14.2	2.8	5.9	n.d.	98.98
7.	74.2	0.40	0.53	2.8	n.d.	15.2	3.2	3.4	n.d.	99.73
8.	71.5	0.57	0.49	4.8	n.d.	14.7	2.8	5.0	n.d.	99.86
9.	74.5	0.31	0.15	0.35	n.d.	13.7	3.2	5.3	0.08	97.59
10.	74.6	0.46	0.35	0.59	n.d.	13.9	2.8	5.1	n.d.	97.80
11.	75.0	0.36	0.33	1.4	n.d.	13.9	2.3	4.4	n.d.	97.69
B. Isoferroplatinum?										
12.	82.9	0.63	0.43	0.60	0.21	10.9	1.1	2.6	n.d.	99.37
13.	81.2	0.75	0.50	0.56	n.d.	11.5	1.0	3.2	n.d.	98.71
14.	83.4	0.67	0.45	0.51	n.d.	11.0	1.2	2.7	n.d.	99.93
15.	81.8	0.60	0.48	0.50	n.d.	11.2	2.1	2.9	n.d.	99.58
16.	80.8	0.56	0.50	0.24	n.d.	12.5	1.1	2.6	n.d.	98.30
17.	81.0	0.52	0.20	3.6	n.d.	11.4	0.47	1.2	n.d.	98.39
C. Tulameenite?										
18.	71.4	n.d.	0.65	n.d.	n.d.	5.5	12.9	2.0	6.9	99.35
19.	73.8	0.44	0.39	0.29	0.33	11.1	9.7	2.9	n.d.	98.95

1. GN87-146B(16), 12 x 32 μm with minor hol in sil, in contact with cmt.
2. GN87-146B(21), 4 x 8 μm with isoferroplatinum and erl in cmt.
3. GN87-146B(27-2), 4 x 8 μm in cmt.
4. GN87-146B(28), 6 x 8 μm with isoferroplatinum, Co>Ni-Fe sulphide and lau, in cmt.
5. GN87-147B(2), 15 x 20 μm with platinian copper in cmt.
6. GN87-147B(7), 10 x 10 μm in cmt.
7. GN87-147B(8), 20 x 25 μm in cmt.
8. GN87-147B(10), 8 x 15 μm in cmt.
9. GN87-146A(1), 5 x 6 μm in cmt.
10. GN87-146A(6), 3 x 5 μm in cmt.
11. GN87-146A(12), 5 x 6 μm in cmt.
12. GN87-146B(13), 10 x 10 μm in cmt.
13. GN87-146B(21), refer to anal. 2.
14. GN87-146B(25), 8 x 9 μm with some lau, in cmt.
15. GN 87-146B(27-1), 10 x 10 μm, with isoferroplatinum and platinian copper in cmt.
16. GN87-146B(28), refer to anal. 5.
17. GN87-148A(6), (polished thin section), 5 x 5 μm in cmt.
18. GN87-146B(17), 30 x 35 μm with some platinian copper in cmt.
19. GN87-146B(27-1), refer to anal. 15.

*Ru was not detected; minimum detection limits in wt % are: Rh,Pd,Ru (0.05), Os(0.10) and Sb(0.07); hol = hollingworthite, sil = silicate, cmt = chromite, lau = laurite, erl = erlichmanite.

Table 2. Electron microprobe analyses of platinian copper from Tulameen

Anal. No.	Weight per cent							
	Pt	Rh	Pd	Cu	Fe	Ni	Sb	Totals
1	33.0	0.10	0.07	65.6	0.17	0.40	0.15	99.49
2	34.9	0.10	0.05	61.9	0.59	0.29	1.3	99.13
3	34.3	0.14	0.08	60.9	1.2	0.78	1.7	99.10
4	36.5	0.10	0.05	60.9	0.37	0.69	0.68	99.29
5	30.4	0.09	0.08	59.2	2.1	3.7	3.2	98.77
Range	28.4-32.4			54.8-63.6	1.3-2.9	0.24-7.1	0.18-6.3	

1. $Cu_{0.85}Pt_{0.14}Ni_{0.01}Rh_{<0.01}Pd_{<0.01}Fe_{<0.01}Sb_{<0.01}$: GN87-148A(11-B) polished thin section, 13 x 30 μm in serpentine.
2. $Cu_{0.83}Pt_{0.15}Fe_{0.01}Sb_{0.01}Rh_{<0.01}Pd_{<0.01}Ni_{<0.01}$: GN87-148B(1), 8 x 40 μm with Pt oxide, geversite, serpentine and chromite.
3. $Cu_{0.81}Pt_{0.15}Fe_{0.02}Ni_{0.01}Sb_{0.01}Rh_{<0.01}Pd_{<0.01}$: GN87-148B(2), 3 x 8 μm with Ni-Sb and irarsite in chromite.
4. $Cu_{0.82}Pt_{0.16}Fe_{0.01}Ni_{0.01}Sb_{<0.01}Rh_{<0.01}Pd_{<0.01}$: GN87-148A(11-C) polished thin section, 15 x 40 μm with magnetite in serpentine.
5. $Cu_{0.77}Pt_{0.13}Ni_{0.05}Sb_{0.02}Rh_{<0.01}Pd_{<0.01}$: GN87-146(4) polished thin section, 10 x 18 μm with Ni-As in serpentine(?) between chromite grains.

Table 3. Electron microprobe analyses of geversite from Tulameen

Anal. No.	Weight per cent								
	Pt	Rh	Ir	Fe	Cu	Ni	Sb	As	Total
1	42.9	n.d.*	n.d.	0.80	0.25	0.22	54.9	1.2	100.27
2	41.4	0.24	0.14	0.92	n.d.	n.d.	55.5	0.28	98.48
3	42.9	0.18	0.42	n.d.	n.d.	0.53	55.7	n.d.	99.73

1. $(Pt_{0.93}Fe_{0.06}Cu_{0.02}Ni_{0.01})\Sigma=1.02(Sb_{1.91}As_{0.07})\Sigma=1.98$: GN87-146A(2), complex multimineralic grain with platinian copper, Ni-Sb and hollingworthite, and enclosed in magnetite/chromite.
2. $(Pt_{0.92}Fe_{0.07}Rh_{0.01}Ir_{<0.01})\Sigma=1.00(Sb_{1.98}As_{0.02})\Sigma=2.00$: GN87-148A(2) (polished thin section), 8 x 10 μm in chromite, in contact with calcite/dolomite.
3. $(Pt_{0.95}Ni_{0.04}Rh_{0.01}Ir_{0.01})\Sigma=1.01Sb_{1.99}$: GN87-148A(3), 8 x 15 μm, in breithauptite with Pt oxide and enclosed in serpentine.

*n.d. = not detected; minimum detection limits in wt %: Fe,Cu,Ni(0.03), Rh(0.05), As,Ir(0.10).

Table 4. Electron microprobe analysis of Pt oxide from Tulameen

	wt %	Range
Pt	78.7	76.2 - 80.3
Rh	0.28	
Ir	0.92	0.59 - 1.3
Fe	0.33	
Cu	4.1	3.5 - 4.7
Ni	4.4	3.0 - 5.5
Sb	2.6	2.1 - 3.0
O*	8.67	

*Oxygen by difference.
GN87-148B(1), with platinian copper, Ni-Sb, geversite(?) and Ni oxide, and surrounded by Mg>Fe silicate, magnetite and chromite.

Table 5. Electron microprobe analyses of various Ni-Sb minerals from Tulameen

Anal. No.	Weight per cent							
	Ni	Cu	Fe	Ir	Pt	Rh	Sb	Total
1	31.1	11.8	0.90	7.0	0.24	0.79	47.8	99.63
2	31.1	0.32	n.d.*	n.d.	1.7	0.14	65.9	99.16
3	57.6	0.26	0.66	n.d.	n.d.	n.d.	40.5	99.02

1. $(Ni_{1.36}Cu_{0.48}Ir_{0.09}Fe_{0.04}Rh_{0.02}Pt_{<0.01})\Sigma=1.99Sb_{1.01}$; GN87-148B(2), 5 x 20 μm, complex multimineralic grain with platinian copper and irarsite, enclosed in chromite.
2. $(Ni_{0.97}Pt_{0.02}Cu_{0.01}Rh_{<0.01})\Sigma=1.00Sb_{1.00}$; GN87-148A(3), 30 x 60 μm, complex multimineralic grain with geversite and Pt oxide, enclosed in serpentine.
3. $(Ni_{2.95}Fe_{0.04}Cu_{0.01})\Sigma=3.00Sb_{1.00}$; GN87-148A(9), 7 x 12 μm complex multimineralic grain with platinian copper, undetermined Ni arsenide and sulphide, surrounded by magnetite which is enclosed in serpentine.

*n.d. = not detected; minimum detection limits in wt %: Fe(0.03), Rh(0.05), Ir, Pt and As(0.10). As was not detected.

Table 6. Electron microprobe analyses of an unusual Ni arsenide from Tulameen

Anal. No.	Weight per cent					
	Ni	Cu	Fe	As	Sb	Total
1	58.8	0.22	4.1	33.3	3.2	99.62
2	60.8	0.37	1.5	34.3	1.9	98.87

1. $(Ni_{6.47}Fe_{0.47}Cu_{0.02})\Sigma=6.96(As_{2.87}Sb_{0.17})\Sigma=3.04$; GN87-146A 5 x 8 μm, complex multimineralic grain with platinian copper, Ni sulphide and small Pt-Fe alloy grain in magnetite.
2. $(Ni_{6.72}Fe_{0.17}Cu_{0.04})\Sigma=6.93(As_{2.97}Sb_{0.10})\Sigma=3.07$; GN87-146B 10 x 23 μm, complex multimineralic grain with undetermined Ni antimonide, platinian copper and geversite, enclosed in magnetite/ chromite.

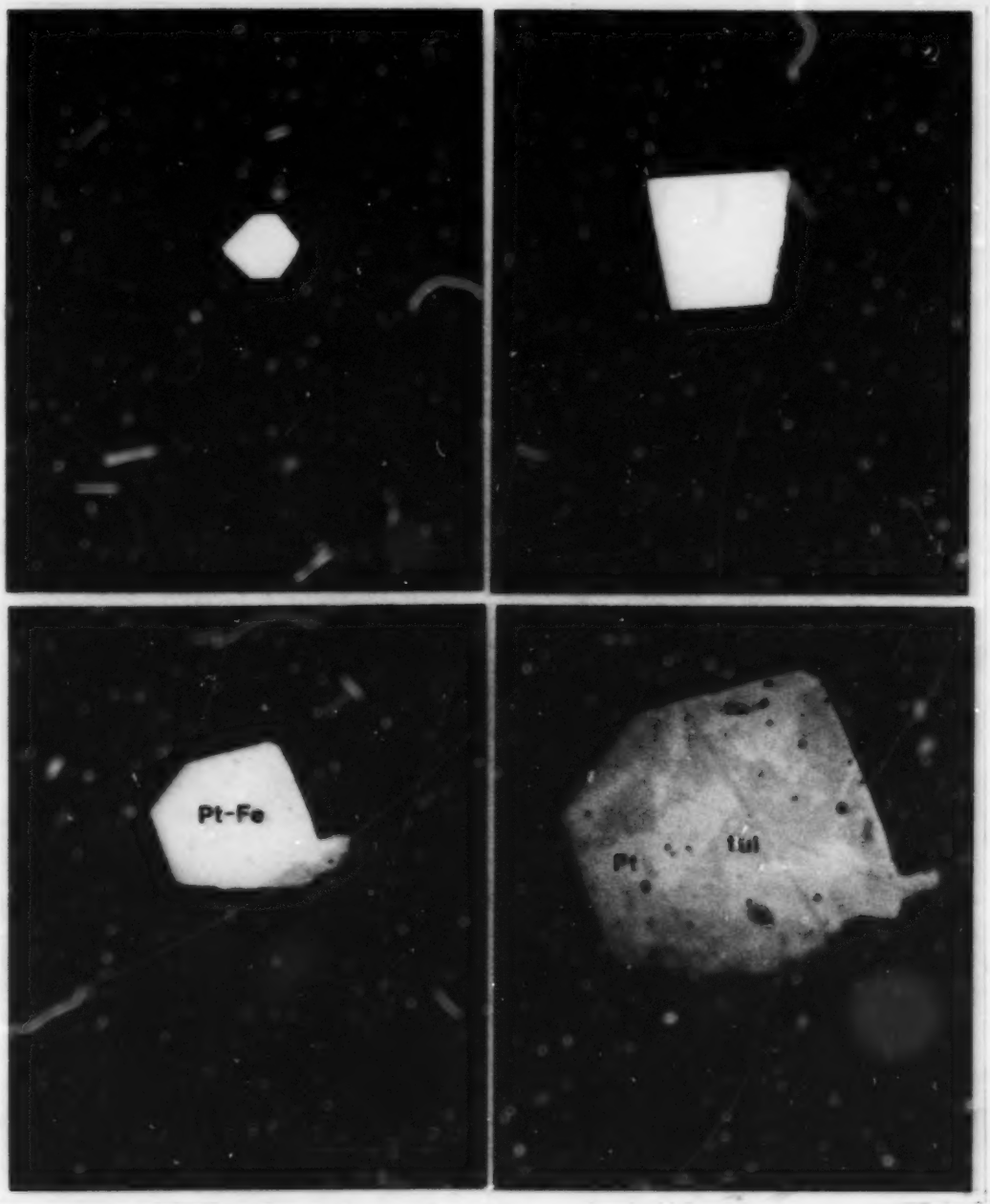

Fig. 1. Euhedral isoferroplatinum(?) inclusion in chromite (cmt). Polished thin section GN87-148A(6).

Fig. 2. Euhedral isoferroplatinum(?) inclusion in chromite. GN87-146B(13).

Fig. 3. Euhedral undefined Pt-Fe alloy with area of platinian copper (Cu-Pt) and attached Mg-Al silicate (sil) included in chromite. GN87-146B(27-1).

Fig. 4. Magnification of Fig. 3 showing intergrowth of tulameenite(?) (= tul), isoferroplatinum(?) (Pt_3Fe) (= Pt) and platinian copper (= Cu-Pt).

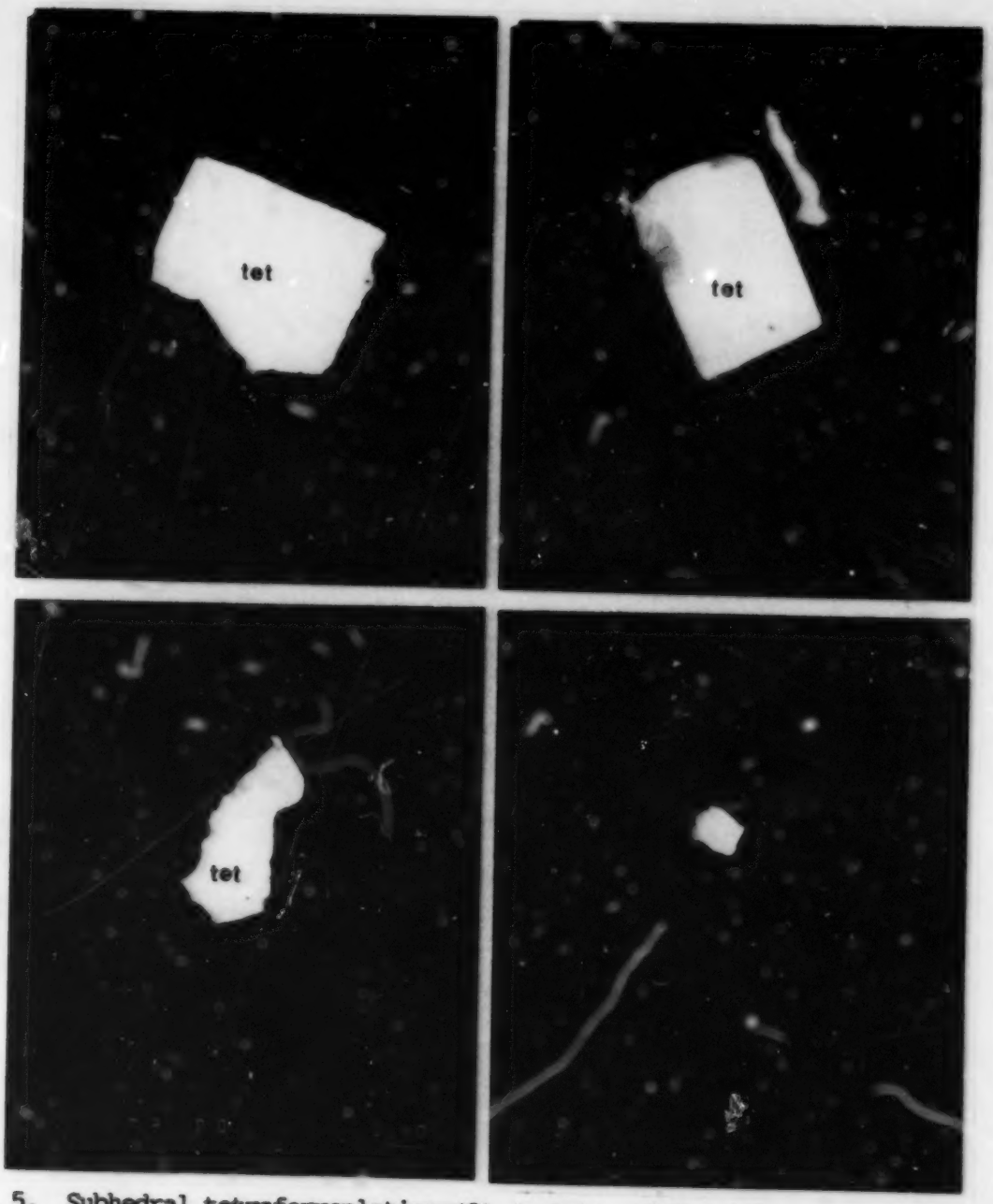

Fig. 5. Subhedral tetraferroplatinum(?) (= tet), with a thin zone of platinian copper, included in chromite. GN87-147B(2).

Fig. 6. Euhedral tetraferroplatinum(?) with hollingworthite (= hol) and nearby irregularly-shaped sperrylite (= spy), both in chromite. GN87-146(20).

Fig. 7. Anhedral tetraferroplatinum(?) abuting against chromite and serpentine (= sil) with magnetite (mag). The alloy contains very small hollingworthite inclusions. GN87-146B.

Fig. 8. A subhedral sperrylite inclusion stradling a fracture in chromite near an area of serpentine (sil). GN87-146B(10).

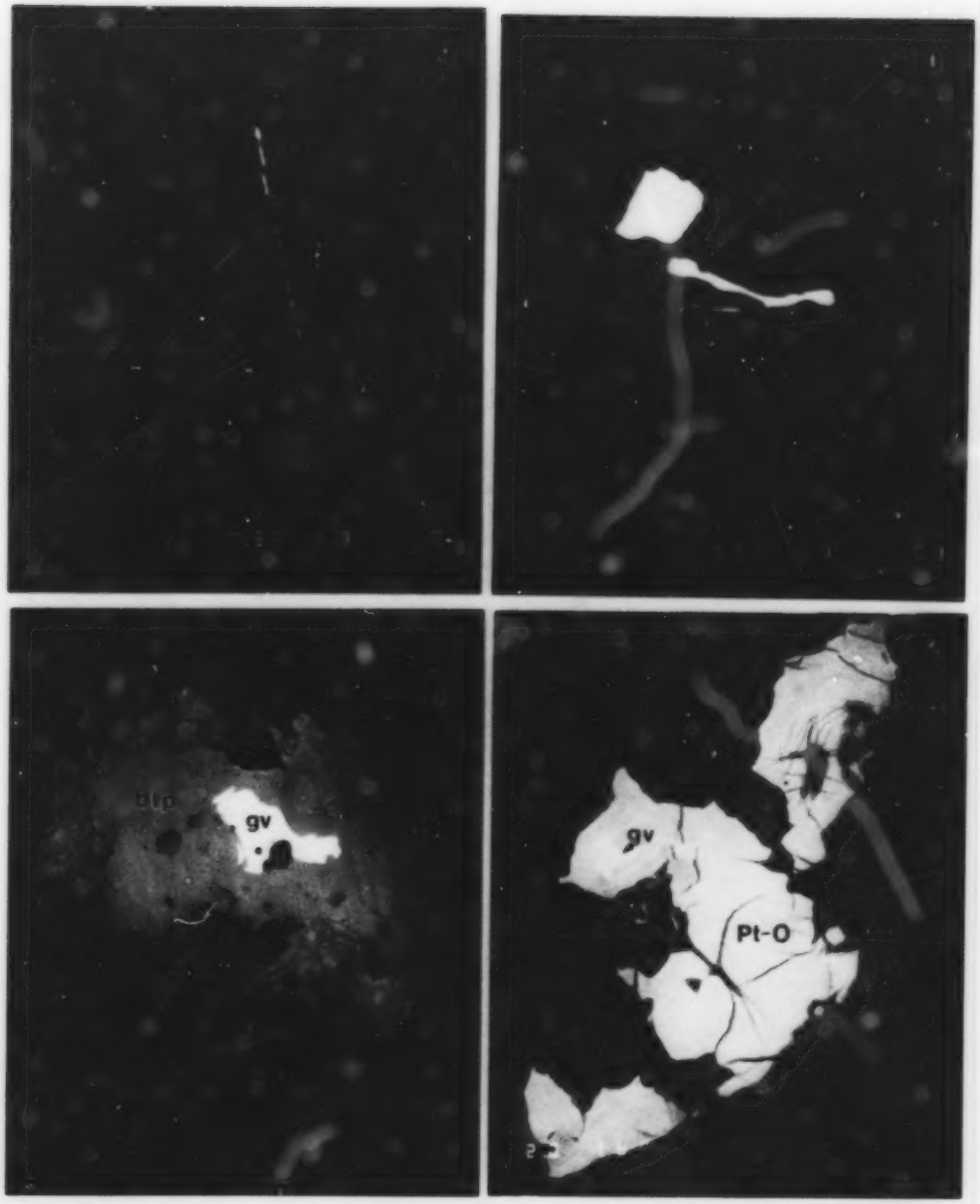

Fig. 9. Fractures in chromite filled by a Mg-Fe silicate (black) magnetite (medium grey) and a Pt antimonide (probably geversite, white). GN87-148(4).

Fig. 10. Fracture in chromite filled by calcite and geversite (gv). Polished thin section GN87-148A(2).

Fig. 11. Complexely altered grain of geversite (gv)-breithauptite (btp) with a Pt oxide rim; all enclosed in serpentine. GN87-148A(3).

Fig. 12. Altered grain, mainly Pt oxide, with remnant geversite, included in chromite. Rims of a Ni antimonide and platinian copper are also present. GN87-148B(1).

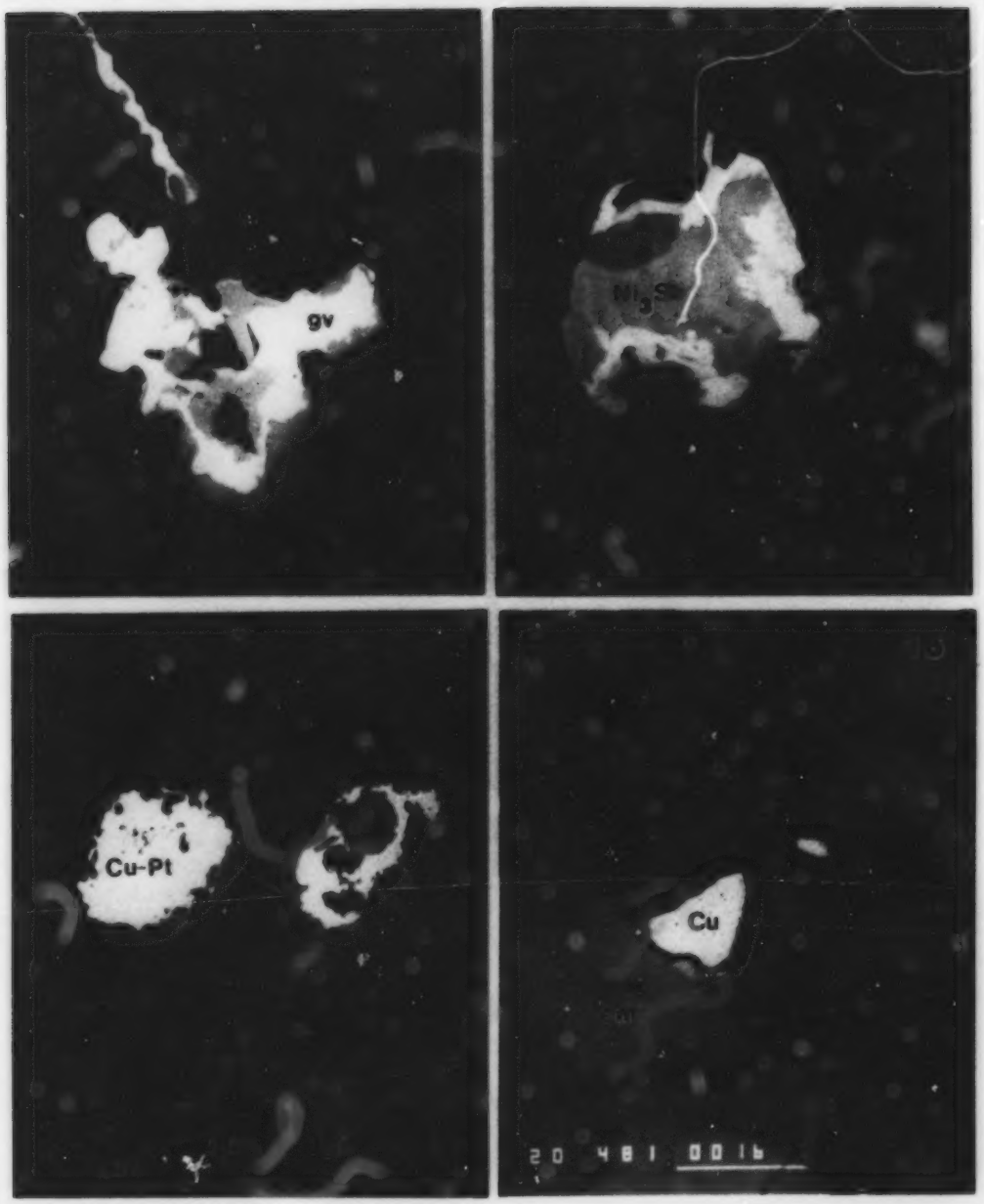

Fig. 13. A complex intergrowth with a core of geversite and zones of breithauptite, platinian copper and hollingworthite included in an Fe-rich zone of chromite (=magnetite). GN87-146A(20).

Fig. 14. Complex intergrowth of platinian copper with Ni antimonide, Ni arsenide and Ni sulphide included in magnetite, itself enclosed by serpentine. GN87-148A(9).

Fig. 15. A magnetite-platinian copper intergrowth in serpentine. Polished thin section GN87-148A(11c).

Fig. 16. Two native copper grains in a carbonate-filled fracture in chromite. GN87-147B(3).